PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Wills et al. (TI-37082) Conf. No. 9565

Serial No. 10/749,416 Group Art Unit: 2863

Filed: December 31, 2003 Examiner: Bui

For: Wavelet Analysis of One or More Time Domain Reflectometry (TDR) Signals to Determine One or More Characteristics of One or More Anomalies in a Wire

DECLARATION OF KENDALL SCOTT WILLS

Commissioner for Patents

P.O. Box 1450

Alexandria, VA 22313-1450

Dear Sir:

I, Kendall Scott Wills, hereby declare:

1. I am one of the named inventors in this patent application.

2. I have been employed by Texas Instruments Incorporated, in Dallas, Texas, since at least as early as May 12, 2003.

3. On information and belief, Exhibit A to this Declaration is a copy of pages of an engineering notebook prepared by Michael Dockins, also one of the named inventors in this patent application, during his employment at Texas Instruments Incorporated. This engineering notebook describes a project that Michael Dockins worked on with me during his employment at Texas Instruments Incorporated, in the United States, in the summer of 2002. This work was performed by us at least as early as May 12, 2003.

4. Pages 14 and 15 of Exhibit A describe the concept of time domain reflectometry (TDR) and the capability of TDR to locate circuit features physically. Page 15 also describes our idea that "Comparative TDR", which uses multiple TDR waveforms of objects with known circuit features, and which compares TDR waveforms of unknown circuit features, with the similarities and differences providing information about the circuitry associated with the unknown waveforms. These pages of the engineering notebook were prepared by Michael Dockins in the United States at least as early as May 12, 2003.

5. Pages 40 through 45 of Exhibit A describe our conception of the idea of using a wavelet transform (WT) in TDR. As described on page 40, the wavelet transform allows both time and frequency resolution to be changed based on the frequencies being examined; this property can be used to overcome limitations of conventional TDR. These pages of the engineering notebook were prepared by Michael Dockins in the United States at least as early as May 12, 2003.

6. Pages 54 through 59 of Exhibit A describe our idea that anomalies of packaged integrated circuit devices can be identified by calculating wavelet power spectra using wavelet transforms, and by then comparing the wavelet analysis results among different integrated circuit devices to determine similarities. These pages of the engineering notebook were prepared by Michael Dockins in the United States at least as early as May 12, 2003.

7. Pages 61 through 65 of Exhibit A describe a successful experiment in analyzing actual integrated circuit devices according to this technique. Pages 68 and 69 of Exhibit A describe the system and software used to perform this experiment. Page 64 illustrates instantaneous power spectra of wavelet transforms of signals applied to a integrated circuit device under test and to reference devices. In each case, these instantaneous power spectra are shown as a function of time from the launch of a time domain reflectivity (TDR) signal, with the density of each plotted point representing the power at the corresponding time and frequency values. As described in those pages, the integrated circuit device under test showed a failure in the connection between a solder bump connection and its die prior to stress ("pre-stress"). The measured instantaneous power spectrum of the wavelet transform for the device under test, pre-

stress (in its failed condition), which is shown in the upper left of page 64, resembled the instantaneous power spectrum shown in the upper right of page 64 for a reference package with no die (which would provide a similar electrical characteristic to a bump-to-die connection failure). After stressing of the device under test and the resulting recovery of that connection failure, the instantaneous power spectrum of the wavelet transform of the device under test, shown in the lower left of page 64, resembled that of a known good device, shown in the lower right of page 64. This experiment was performed in the United States at least as early as May 12, 2003, and these pages of the engineering notebook were prepared by Michael Dockins in the United States at least as early as May 12, 2003.

8. Pages 72 and 73 of Exhibit A describe conclusions from our experiment, in that the wavelet transform technique allows time-frequency analysis of TDR signals, which is useful in identifying circuit and defect properties. These pages of the engineering notebook were prepared by Michael Dockins in the United States at least as early as May 12, 2003.

9. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Kendall Scott Wills

Kendall Scott Wills

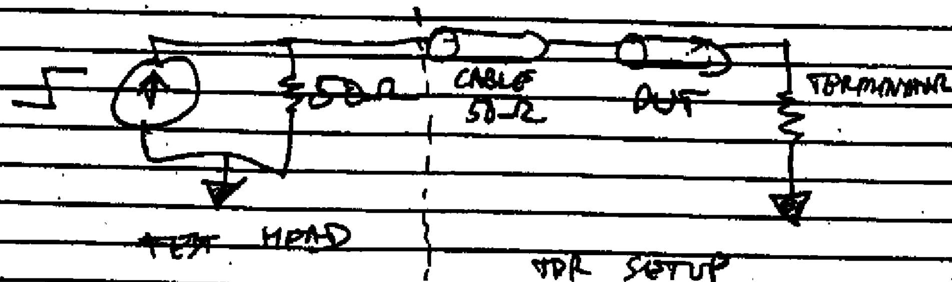
Date: 6/22/, 2006

EXHIBIT A

PROJECT BACKGROUND

TIME DOMAIN REFLECTOMETRY (TDR)

A TDR SYSTEM CONSISTS OF AN OSCILLOSCOPE, A STEP FUNCTION GENERATOR, A WIDE-BANDWIDTH SAMPLER AND A DUAL-TIPPED PROBE

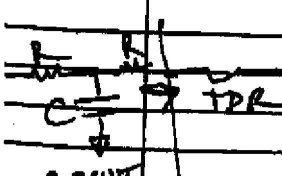


THE FUNCTION GENERATOR IN THE TEST HEAD PRODUCES A FAST RISE TIME STEP SIGNAL, THE RISE TIME OF THE SIGNAL DIRECTLY AFFECTS THE RESOLUTION OF TDR

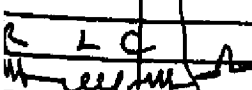
$$\delta_{res} = \frac{c_0}{\sqrt{\epsilon_r}} \frac{t_{rise}}{2}$$

dielectric cst. TDR RESOLUTION

AT ANY IMPEDENCE BOUNDARY, A PORTION OF THE SIGNAL IS REFLECTED & THE REST TRANSMITTED. TDR MEASURES THE REFLECTED SIGNAL PORTIONS AS THEY RETURN TO THE SAMPLER PORTION OF THE TEST HEAD



WHEN A SHUNT CAPACITOR IS ENCOUNTERED, THE REFLECTED TDR SIGNAL SHOWS A VOLTAGE DIP BECAUSE THE CAPACITOR MUST CHARGE FROM THE INITIAL POTENTIAL TO THE POTENTIAL OF THE INCIDENT WAVEFORM



WHEN A SERIES ~~CAPACITOR~~ INDUCTOR IN ENCOUNTERED, THE REFLECTED TDR SIGNAL SHOWS A VOLTAGE SPIKE. THE CURRENT THROUGH THE INDUCTOR CAN'T CHANGE AS FAST AS THE SIGNAL TRIES TO DRIVE IT, SO THE FRONT-END VOLTAGE INCREASES TO COMPENSATE

SIGNATURE DATE [redacted]

ADVANTAGES OF TDR

① PROVIDES INFORMATION ABOUT ~~[illegible]~~ CIRCUITRY INTERNAL TO SEMICONDUCTOR PACKAGING

② CAN BE USED TO LOCATE CIRCUIT FEATURES TEMPORALLY

③ DATA ACQUISITION AND INTERPRETATION IS QUICK

④ COMPARATIVE TDR CAN BE USED TO LOCATE CIRCUIT FEATURES PHYSICALLY

— COMPARATIVE TDR —

USES MULTIPLE TDR WAVEFORMS OF OBJECTS WITH KNOWN CIRCUIT FEATURES & COMPARES TO WAVEFORM ~~OF~~ UNKNOWN CIRCUIT FEATURES. SIMILARITIES AND DIFFERENCES PROVIDE INFORMATION ABOUT THE UNKNOWN WAVEFORM'S ASSOCIATED CIRCUITRY

DISADVANTAGES OF TDR

① PROVIDES NO INFORMATION ABOUT THE CAUSE OF A FAILURE

E.G.: A SHORT CIRCUIT CAUSED BY A THICK COPPER WIRE APPEARS THE SAME AS A SHORT CIRCUIT CAUSED BY A THIN GOLD FILAMENT

② NOT USEFUL FOR MULTI-CHIP MODULES

THE WAVEFORMS RESULTING FROM MULTIPLE CIRCUIT PATHS ARE CURRENTLY EXCEEDINGLY DIFFICULT TO INTERPRET

③ TDR PROVIDES ONLY TIME DOMAIN INFORMATION

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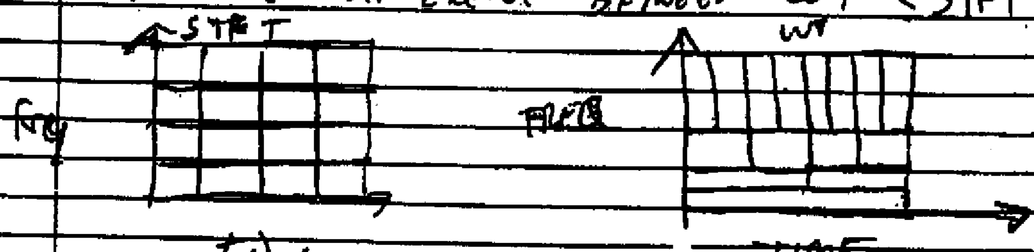
WAVELETS.

THE NEXT T-F ANALYSIS METHOD CHOSEN WAS WAVELET ANALYSIS. WAVELET ANALYSIS IS A RELATIVELY NEW TECHNIQUE, AT LEAST FOR WIDESPREAD APPLICATION.

THE WAVELET TRANSFORM (WT) CAN OVERCOME ONE OF THE PROBLEMS OF THE STFT & OTHER FT-BASED APPROACHES. WITH FT-BASED APPROACHES A SINGLE FREQUENCY RESOLUTION MUST BE CHOSEN FOR ALL FREQUENCY BANDS. A HIGH RESOLUTION IN FREQUENCY RESULTS IN LOW TIME RESOLUTION. HIGH FREQUENCIES NEED GOOD TIME RESOLUTION TO BE DETECTED AND CHARACTERIZED WELL. LOWER FREQUENCIES NEED BETTER FREQ. LOCALIZATION, BUT NOT AS HIGH A TIME RESOLUTION. AS SUCH, FT-BASED APPROACHES ARE OPTIMIZED (USUALLY) FOR DETECTING CERTAIN CHARACTERISTICS.

THE WT ALLOWS THE TIME & FREQUENCY RESOLUTION TO CHANGE, BASED ON THE FREQUENCIES BEING EXAMINED. HIGH FREQUENCIES GET HIGH ~~[illegible]~~ RES. & LOWER FREQ RES. LOW FREQUENCIES GET HIGHER FREQ. RES AND LOWER TIME RES.

THE WT DOES NOT OVERCOME THE HEISENBERG INEQUALITY. THE HEISENBERG BOXES SHOW THE DIFFERENCE BETWEEN WT & STFT



ALL OF THE HEISENBERG BOXES HAVE ~ THE SAME AREA (THE MINIMUM RESOLUTION BASED ON UNCERTAINTY). WITH THE WT, THE SHAPE OF THE BOX IS MODIFIED.

SIGNATURE DATE [redacted] 12

THE WAVELET TRANSFORM IS EXPRESSED AS

$$W(a,b) = \int_{t=-\infty}^{\infty} x(t) \frac{1}{\sqrt{a}} \psi^*\left(\frac{t-b}{a}\right) dt$$

where a is the scale
b is the translation
ψ is the Mother wavelet

The mother wavelet is the absolutely integrable function that is used as a basis for REPRESENTING THE FUNCTION. THE SCALE IS THE DILATION FACTOR THAT COMPRESSES OR STRETCHES THE WAVELET. THE TRANSLATION IS THE FACTOR THAT MOVES THE MOTHER WAVELET ALONG THE TIME AXIS.

THE WT USES THE MOTHER WAVELET AS A BASIS FOR REPRESENTING THE FUNCTION, JUST LIKE THE FT USES COMPLEX EXPONENTIALS (SINES COSINES) TO REPRESENT THE SIGNAL.

SCALE IS RELATED TO FREQUENCY BUT THEY ARE NOT DIRECTLY PROPORTIONAL. SCALE IS RELATED TO A FREQUENCY BAND (FREQ SIDE OF HEIS-BOX) RATHER THAN A SPECIFIC FREQ. ADDITIONALLY NOT ALL WAVELETS HAVE TRUE FREQUENCIES LIKE SINE/COS WAVES. BECAUSE OF THIS CENTER FREQUENCIES ARE USED TO GIVE APPROXIMATE FREQ REPRESENTATIONS FOR SCALE.

$$\omega_{scale} = \frac{\Delta t\, \omega_c}{a}$$

HIGH SCALE → LOW F
LOW SCALE → HIGH F

where a is scale
Δt is sampling period
ω_c is the center frequency of the mother wavelet.

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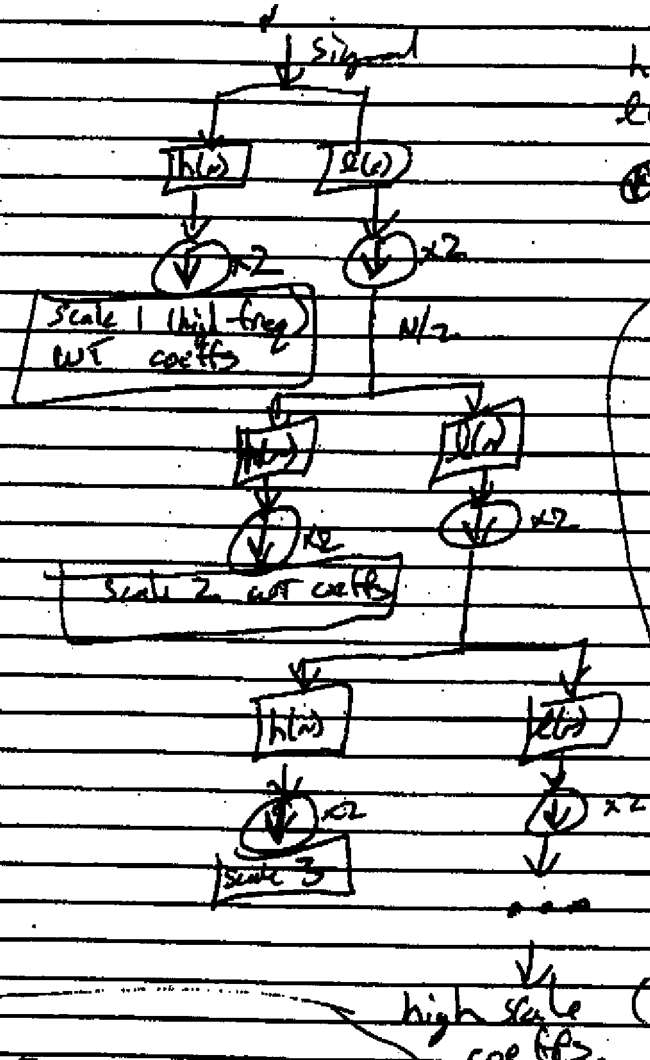
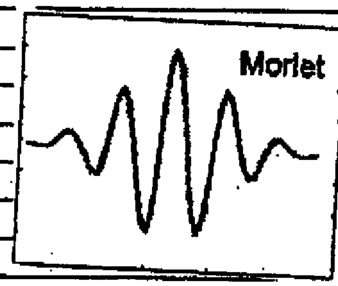
Sub-band coding was used to implement the WT. The following diagram explains SBC



h(x): high-pass filter
l(x) = low-pass filter
⊕ = downsample

WAVELET EXAMPLE



THE FILTER COEFFICIENTS CAN BE OBTAINED USING THE DILATION EQUATION

$$\phi(x) = \sum_{k=0}^{N} c_k \phi(2x-k)$$

where the c_k are the coefficients for the high pass filter. THE WAVELET ~~COEFFICIENTS~~ EQUATION GIVES THE LOW PASS COEFFS

$$\psi(x) = \sum_{1-N}^{1} (-1)^k c_{1-k} \phi(2x-k)$$

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THE FIRST WAVELET TRANSFORM ~~WA~~ WRITTEN WAS USED THE HAAR WAVELET

Haar_4

HAAR WAVELET

THE HAAR WAVELET IS THE MOST SIMPLE AND COEFFS. CAN BE CALCULATED BY HAND EASILY FOR CODE VERIFICATION PURPOSES. I THOUGHT THE HAAR WAVELET MIGHT BE A GOOD BASIS FOR THE TDR SIGNALS, WHOSE SHAPE RESEMBLES THE STEP FUNCTION. HaarDWT.m IS THE CODE

```
C:\MATLAB6p1\work\Required\HaarDWT.m                                  Page 1
[redacted]                                                            2:31:19 PM

function [coeffs, numScales] = HaarDWT(data);

%[coeffs, numScales] = HaarDWT(data);
%
%calculates the wavelet coefficients using haar wavelet
%
%INPUT:
%
%   data:    sample signal data
%
%OUTPUT:
%
%   coeffs:  the wavelet coeffients calculated
%
%   numScales:  the number of scales used
%
%
%
%COPYRIGHT 2002

%Michael Dockins
%Houston Device Analysis Operations

%Texas Instruments, Inc.
%12201 Southwest Freeway
%Stafford, TX 77477

%This code  may not be reproduced in whole or in part without express written
 permission of Texas Instruments.

%INFORMATION

%HaarDWT.m
%22 July 2002

%HISTORY

%Created: 22 July 2002

%Date                 Time         Change
        Modified by
%25 July              13:40        Corrected alg. for wavlet coeff calculation
           Michael Dockins
%1  Aug               11:10        Implemented sub-band coding through convolut
on         Michael Dockins
%13 August            08:40        Changed matrix rejection to nested if
```

```
C:\MATLAB6p1\work\Required\HaarDWT.m
[redacted]
                    Michael Dockins                                   2:31:
%
%

%orient data vector correctly (row vector)
%reject data if a matrix instead of a vector

[numRows,numCols] = size(data);
size = numCols;

if (numRows~=1)
    if (numCols~=1)
        error('This function currently works only on vectors, not matrices
');
    end
end

if (numRows == 1)
    size = numRows;
    data = data';
end


clear numRows;
clear numCols;

if ((log2(size)-floor(log2(size)))~=0)                       %test if data length
 a power of two
    error('Data length must be a power of 2');
end

%create coefficients
%NOTE:  all multiplied by sqrt(2) to allow for reversal of filtering (i.e.
verse WT)

%scaling function coefficients
h0 = 1*1/sqrt(2);
h1 = h0;

%wavelet function coefficients
g0 = -h0;
g1 = h0;

%filters for sub-band coding
lowFilter = [h0 h1];
highFilter = [g0 g1];
```

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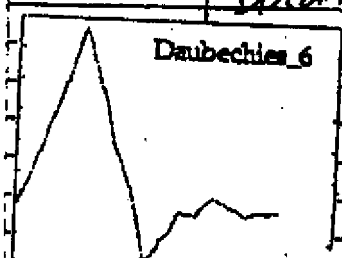
 PROJECT NAME FDA TDRS NOTEBOOK NO. 1

```
[redacted]\HaarDWT.m                                              Page 3
                                                              2:31:17 PM

numScales = log2(size);                                  %number of scales to a
nalyse at

coeffs = [];                                             %matrix to hold the c
oefficients

myData = data;                                           %signal to pass throu
gh filter bank

for lcv=1:1:numScales                                    %at each scale

    mySize=length(myData);                               %get length of curren
t signal
    highParts=conv(highFilter,myData);                   %high-pass filter it
    lowParts=conv(lowFilter,myData);                     %low-pass filter it

    highParts=highParts(2:2:mySize);                     %down-sample by 2
    lowParts=lowParts(2:2:mySize);

    coeffs = [highParts coeffs];                         %store the high-pass
coefficients
    myData = lowParts;                                   %send the low-pass co
efficients to the next level

end

coeffs = [myData coeffs];                                %store the last low-p
ass coefficients
coeffs = fliplr(coeffs);                                 %flip the coefficient
s so the low-scale coefficients appear first
```

THE SECOND WAVELET FAMILY IMPLEMENTED WAS DAUBECHIES. I CHOSE THE WAVELET WITH 4 VANISHING MOMENTS. THIS WAVELET IS VERY POPULAR FOR GENERAL USE & DETECTS DISCONTINUITIES WELL. DAUB4DWT.M IS THE CODE



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DATE [redacted] 19

DATE 19

C:\MATLAB...\work\Required\Daub4DWT.m [redacted] Page 1 2:21:41 PM

```
function [coeffs, numScales] = Daub4DWT(data);

%[coeffs, numScales] = Daub4DWT(data);
%
%calculates the wavelet coefficients using Daubechies D4 wavelet
%
%INPUT:
%
%   data:     sample signal data
%
%OUTPUT:
%
%   coeffs:  the wavelet coefficients calculated
%
%   numScales:  the number of scales used
%
%
%
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%Michael Dockins
%Houston Device Analysis Operations

%Texas Instruments, Inc.
%12203 Southwest Freeway
%Stafford, TX 77477

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%INFORMATION

%Daub4DWT.m
%22 July 2002

%HISTORY

Created: 22 July 2002

%te              Time          Change
       Modified by
  July           15:25         Added comments
       Michael Dockins
  July           10:50         Moved plotting to its own function
       Michael Dockins
  ily            14:10         Added help comments
```

C:\MATLAB...\work\Required\Daub4DWT.m [redacted] 2:21

```
               Michael Dockins
%13 August           09:40       Changed matrix rejection to nested if
               Michael Dockins
%

%orient data vector correctly (row vector)
%reject data if a matrix instead of a vector

[numRows,numCols] = size(data);
size = numCols;
if (numRows ~= 1)
    size = numRows;
    data = data';
end
if (size==1)
    error('This function currently works only on vectors, not matrices.'
end

clear numRows;
clear numCols;

if ((log2(size)-floor(log2(size)))~=0)                          %test if data leng
 a power of two
    error('Data length must be a power of 2');
end

%create coefficients
%NOTE:  all multiplied by sqrt(2) to allow for reversal of filtering (i.
verse WT)

h0 = (1+sqrt(3))/(4*sqrt(2));
h1 = (3+sqrt(3))/(4*sqrt(2));
h2 = (3-sqrt(3))/(4*sqrt(2));
h3 = (1-sqrt(3))/(4*sqrt(2));

g0 =  h3;
g1 = -h2;
g2 =  h1;
g3 = -h0;

lowFilter = [h0 h1 h2 h3];                           %for future use in convolution ma
highFilter = [g0 g1 g2 g3];

numScales = log2(size);                                         %number of scales
nalyse at
```

C:\... August 13, 2002 Page 3 2:21:41 PM

```
coeffs = [];                                         %matrix to hold the c
oefficients

myData = data;                                       %signal to pass throu
gh filter bank

for lev=1:1:numScales                                %at each scale

    mySize=length(myData);                           %get length of curren
t signal
    highParts=conv(highFilter,myData);               %high-pass filter it
    lowParts=conv(lowFilter,myData);                 %low-pass filter it

    highParts=highParts(2:2:mySize);                 %down-sample by 2
    lowParts=lowParts(2:2:mySize);

    coeffs = [highParts coeffs];                     %store the high-pas
coefficients
    myData = lowParts;                               %send the low-pass c
efficients to the next level

end

coeffs = [myData coeffs];                            %store the last lowp
ass coefficients
coeffs = fliplr(coeffs);                             %flip the coefficient
s so the low-scale coefficients appear first

%Verification attempts
%u1=FWT_PO(data,1,lowFilter);
%[v,s]=Daub4DWT2(data);
%x=wt(data,lowFilter,highFilter,numScales);
%y=mdwt(data,lowFilter,numScales);
%z=coeffs-y;
%y=y;
```

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THE WT (Haar) SHOWS A LOW FREQUENCY SIGNAL PRESENT THROUGHOUT THE DURATION OF THE SIGNAL. (ONE SCALE IS CONSTANT) THE Haar wavelet is a step function, SO IT IS AN EXCELLENT BASIS AND PROVIDES PRECISE RESULTS.

THE WT (DAUB) SHOWS A LOW FREQ SIGNAL IN THE SAME SCALE AS THE Haar wavelet. THE Daub Wavelet also shows high frequency components where the step function transitions from high to low. IF OUR GOAL IS TO DETECT SHARP TRANSITIONS DAUB MIGHT WORK BETTER THAN Haar.

FOR THE STEP FUNCTION THE Haar wavelet-based DWT PRODUCED THE BEST RESULTS. FOR THIS REASON, IT MAY BE LIKELY THE HAAR WAVELET WILL BE THE BEST CHOICE FOR ANALYZING TDR SIGNALS.

BECAUSE THE TDR SIGNAL IS NOT EXACTLY A STEP FUNCTION, BOTH wavelets will BE USED TO ANALYZE TDR SIGNALS.

SIGNATURE

DATE [redacted]9

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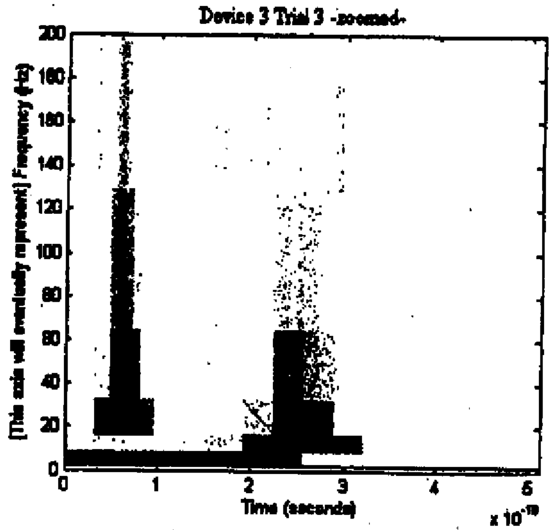
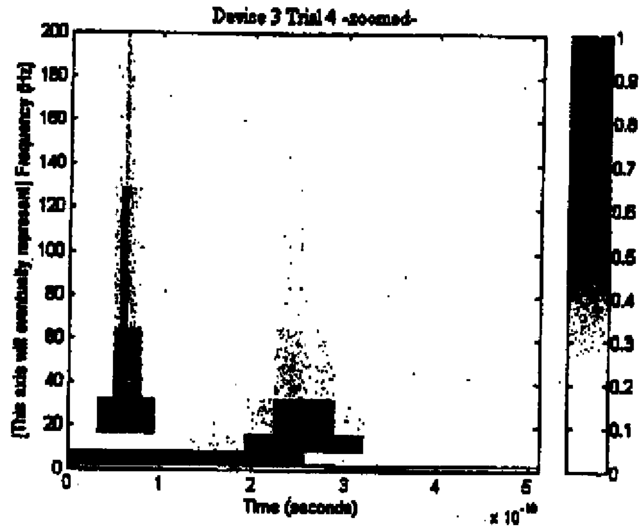
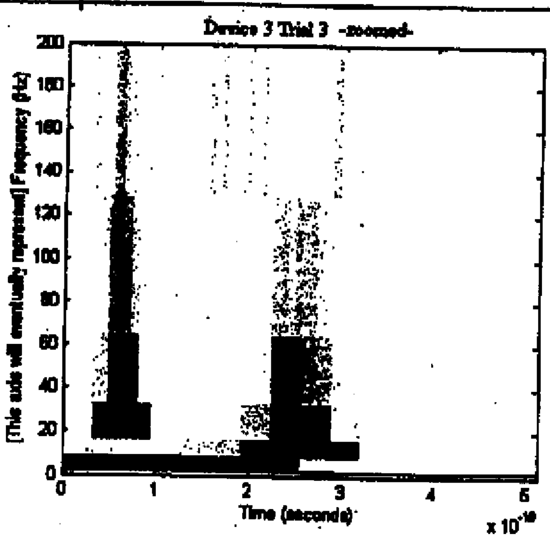
HAAR ANALYSIS

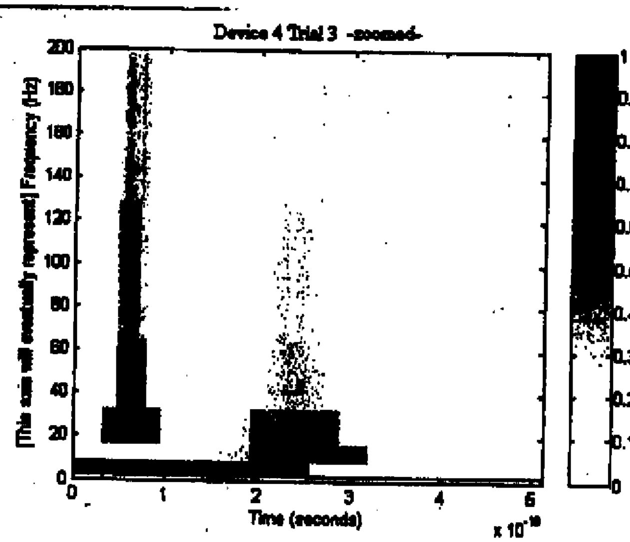
THE WT USING THE HAAR WAVELET WAS TESTED ON TWO TRIALS OF UNIT 3 (NO DIC). THE RESULTS WERE VISUALLY SIMILAR. THE WT (HAAR) IS REPEATABLE FOR TDR SIGNALS





THE WT (HAAR) WAS ALSO USED IN TWO SIMILAR UNITS (4 & 3) WITH THEIR DIC REMOVED. THE RESULTS WERE VISUALLY SIMILAR. THE WT (HAAR) IS CONSISTENT





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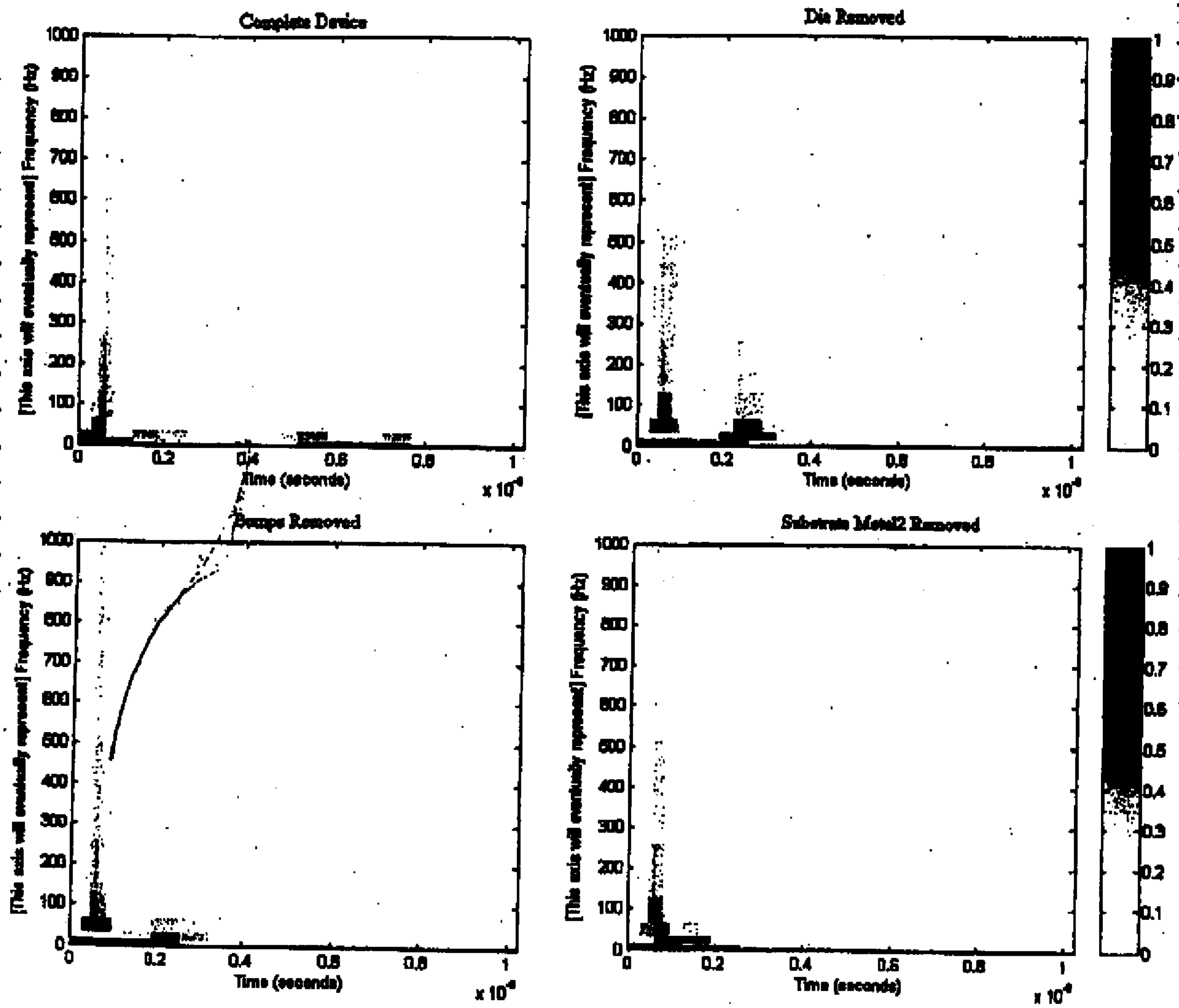
THE WT(HAAR) WAS THEN USED ON UNITS
IN ALL FOUR STATES PREPARED
U1T1, U3T1, U5T1, U7T1



WT Using Haar Wavelets for Four Dissimilar Units

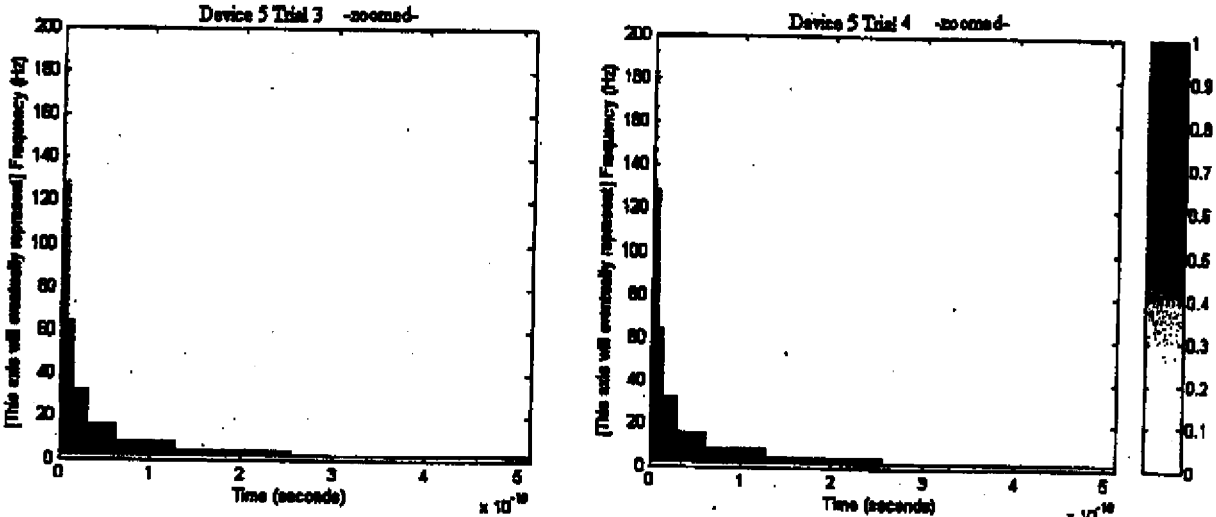
THE WT (HAAR) SHOWS PROGRESSION; THERE
ARE VISIBLE DIFFERENCES BETWEEN UNITS
IN DIFFERENT STATES.

SIGNATURE DATE [redacted]19

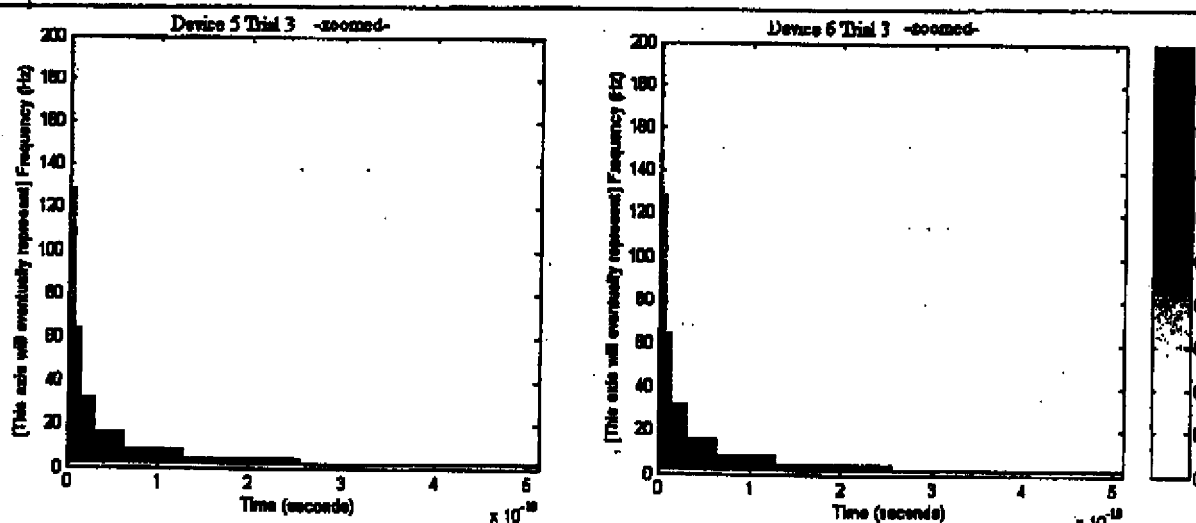
PROJECT NAME FDATDRS NOTEBOOK NO. 1

DAUB 4 ANALYSIS

THE WT USING THE DAUBECHIES WAVELET WAS TESTED ON TWO TRIALS OF UNIT 5 (no die or bumps). THE RESULTS WERE VISUALLY SIMILAR. THE WT(DAUB) IS REPEATABLE FOR TDR SIGNALS



THE WT(DAUB4) WAS ALSO USED ON TWO SIMILAR UNITS (5&6) w/ ~~BOTH~~ DIE & BUMPS REMOVED. THE RESULTS WERE VISUALLY SIMILAR. THE WT(DAUB4) IS CONSISTENT



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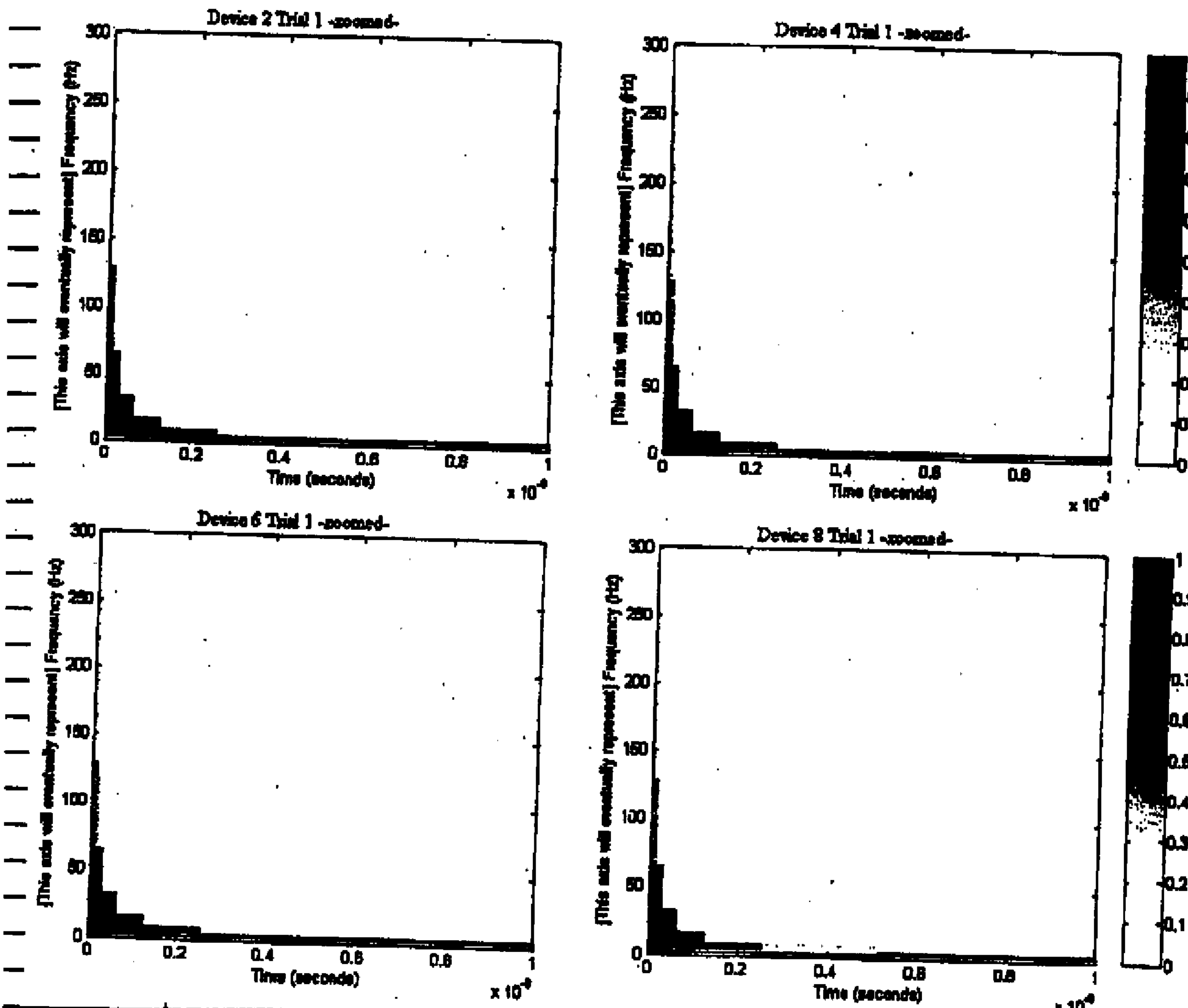
DATE 19

 PROJECT NAME FDATDRS NOTEBOOK NO.

THE WT (DAUB) WAS THEN USED ON UNITS IN
ALL FOUR PREPARED STATES
U2H, U4H, U6H, U8H



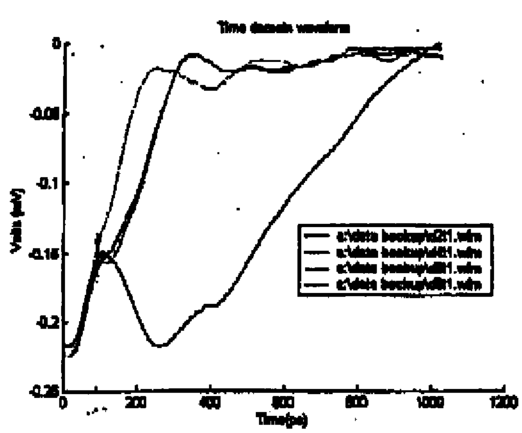
WT Using D4 Wavelets for Four Dissimilar Units

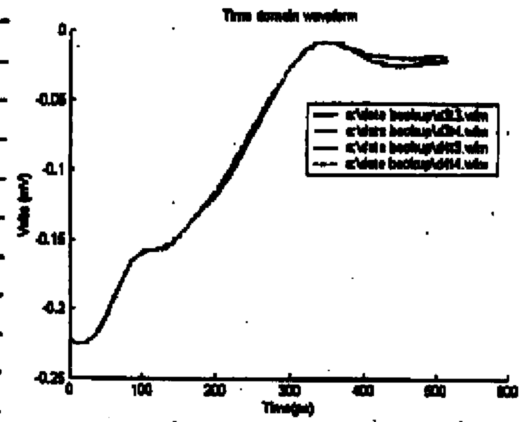
THE WT (DAUB4) SHOWS PROGRESSION BUT IT
IS FAR LESS NOTICABLE THAN IN THE
HAAR WT.

SIGNATURE DATE [redacted]

59 PROJECT NAME [illegible] NOTEBOOK NO. 1

WT(HAAR) ANALYSIS





FROM ~~[illegible]~~ - ~~[illegible]~~ ps, THE TDR WAVEFORMS ARE IDENTICAL. THE ~~INITIAL~~ VOLTAGE DIP AT THE BEGINNING OF THE TDR SIGNAL IS THE RESULT PRIMARILY OF THE PROBE TIP CONTACTING THE UNIT.

AFTER THIS POINT, THERE ARE DIFFERENCES BETWEEN THE DEVICES, BUT THEY CAN BE VERY SLIGHT AND DIFFICULT TO INTERPRET, ESPECIALLY FOR UNITS WHOSE CIRCUIT PATHS ARE NEARLY THE SAME LENGTH

NEED

A TECHNIQUE THAT COULD EMPHASIZE THE DIFFERENCES WOULD AID COMPARATIVE TDR GREATLY AND COULD HELP BETTER ISOLATE DEFECTS.

SOLUTION

WAVELET ANALYSIS, ESPECIALLY USING HAAR WAVELETS, CAN BE USED TO HELP HIGHLIGHT THE DIFFERENCES. ~~BECAUSE~~ THE HIGH FREQUENCIES WHICH ARE ASSOCIATED WITH THE ~~MORE~~ CHANGES OF THE WAVEFORM CAN BE COMPARED BETWEEN UNITS TO DETERMINE IF THEY EXHIBIT SIMILAR CHANGES.

THE HAAR WT IS ALSO VERY USEFUL AT IDENTIFYING THE RESISTIVE (FLAT TDR SIGNAL) AREAS IN THE SIGNAL. THESE AREAS EXHIBIT ONLY LOW FREQUENCIES AND CAN BE EASILY IDENTIFIED USING THE HAAR WAVELET AS A BASIS

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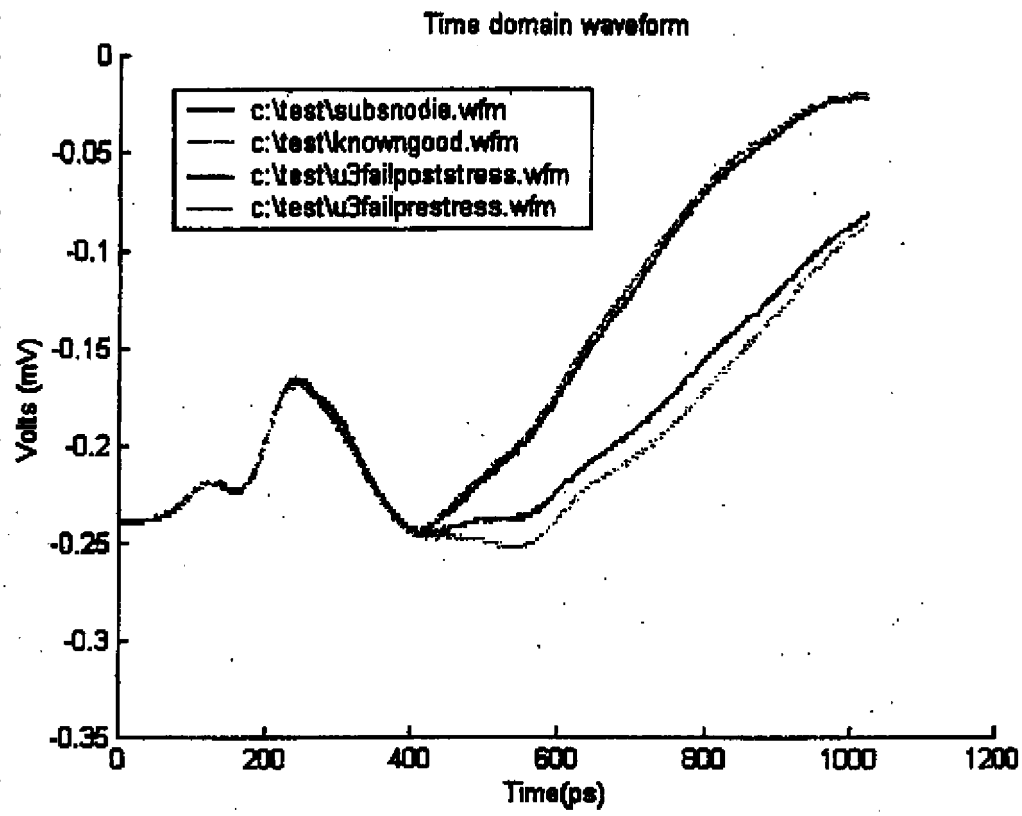
PROJECT NAME FDATIVES NOTEBOOK NO. 1

THE WT (HAAR) WAS USED ON A SERIES OF TDR WAVEFORMS AQUIRED BY OMAR DIAZ de LEON FOR COMPARATIVE TDR. THE DEVICE ORIGINALLY SHOWED TO HAVE A FAILURE AT THE BUMP-TO-DIE INTERFACE.

AFTER STRESSING THE UNIT ELECTRICALLY THE UNIT RECOVERED & ITS NEW SIGNATURE RESEMBLED THAT OF A GOOD UNIT



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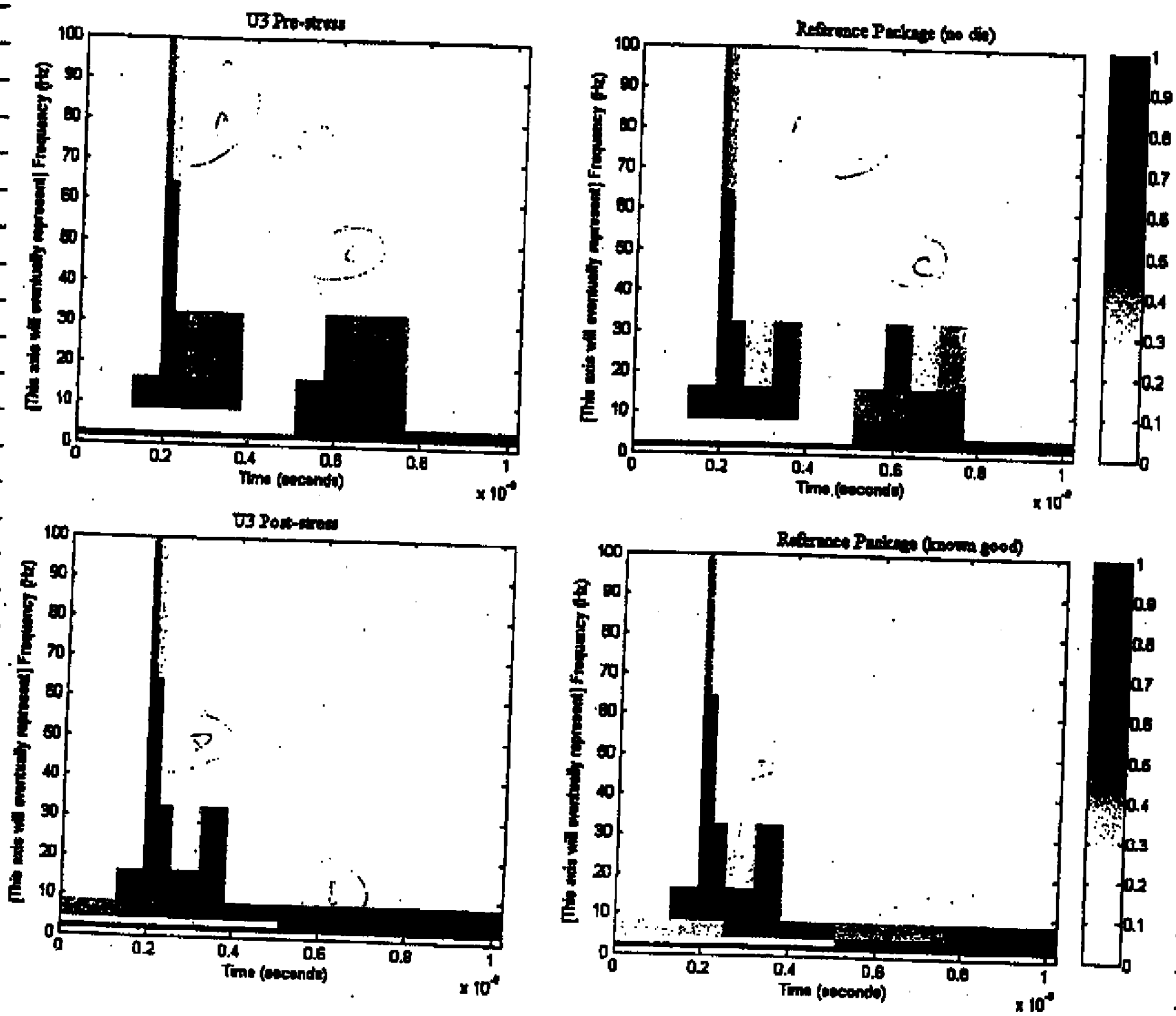
 PROJECT NAME [illegible] NOTEBOOK NO. 1

WT (HAAR) ANALYSIS FOR RECOVERED UNIT



WT using Haar wavelets for Four Dissimilar Test Units

AS INDICATED IN THE TIME DOMAIN, PRESTRESS RESEMBLES NODIE GREATLY, AS POST-STRESS DOES KNOWN GOOD

BOTH REFERENCE PACKAGES EXHIBIT SHARPER TIME TRANSITIONS THAN THE TESTED UNIT. THE H-BOXES MOVE FROM ONE COLOR TO THE NEXT & STAY THERE FOR A FEW BOXES WHILE THE TESTED UNITS CHANGE COLOR AT EACH BOX, BUT BY SMALLER INCREMENTS

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THE WAVELET TRANSFORM SHOWS PROMISE IN HELPING TO DIFFERENTIATE BETWEEN TDR WAVEFORMS AND MAY BE HELPFUL IN FINDING CHARACTERISTICS OF THE WAVEFORMS.

NO DOCUMENTATION FOR USING WAVELETS TO HELP DIFFERENTIATE SIGNALS using WAS FOUND IN MY RESEARCH.

NO DOCUMENTATION FOR USING WAVELETS TO AID IN TDR ANALYSIS WAS FOUND IN MY RESEARCH

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 PROJECT NAME TDA TDRS NOTEBOOK NO. 1

EQUIPMENT USED:

HARDWARE:

GENERIC PC

TEKTRONIX 11801C DIGITAL SAMPLING OSCILLOSCOPE

TEKTRONIX SD-24 20 GHZ TDR SAMPLING HEAD

NATIONAL INSTRUMENTS PCI-GPIB INTERFACE BOARD

NATIONAL INSTRUMENTS 488.2 (WIN9x)

SOFTWARE: TDA SYSTEMS ICONNECT 1.5

MATHWORKS MATLAB R12.1

PROBE:

TI CALIBRATION LAB-CREATED 50Ω DUAL TIP PROBE

SIGNATURE

WAVELET SOFTWARE TOOLS EVALUATED:

RICE WAVELET TOOLBOX
http:// www.dsp.rice.edu/software/rwt.shtml

WAVELAB 802 (STANFORD UNIVERSITY)
http:// www-stat.stanford.edu/~wavelab/

WAVELET TOOLS FROM UNIVERSITY OF COLORADO'S
PROGRAM IN ATMOSPHERIC & OCEANIC SCIENCES
http://paos.colorado.edu/research/wavelets

UVI WAVE 3 (UNIVERSITY OF VIGO)
http://cas.ensmp.fr/~chaplais/UviWave/About_UviWave.htm

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 PROJECT NAME [illegible] NOTEBOOK NO. 1

SOLUTION FOUND:

THE WAVELET TRANSFORM CAN BE USED TO REPRESENT AND VISUALIZE TDR WAVEFORMS IN A DIFFERENT MANNER. THE WT AIDS IN DETERMINING BOTH WHAT WAVEFORM FEATURES OCCUR AND WHEN THEY OCCUR. BY SEPARATING HIGH & LOW FREQUENCIES, FEATURES MAY BE MORE EASILY OBSERVED.

BY SEPARATING HIGH & LOW FREQUENCIES AND LOCATING THEM TEMPORALLY, THE WT CAN ALLOW FOR EASIER COMPARISON OF WAVEFORMS THAN TDR.

THE WT CAN BE USED TO IDENTIFY FREQUENCY COMPONENTS PRESENT IN A TDR SIGNAL AS WELL AS WHEN THE COMPONENTS ARE PRESENT. THIS ALLOWS TIME-FREQUENCY ANALYSIS TO BE PERFORMED ON TDR SIGNALS. THE FREQUENCY INFORMATION MAY BE USEFUL IN IDENTIFYING CIRCUIT AND DEFECT PROPERTIES

~~THE STFT IS USED~~

COMMERCIALLY AVAILABLE SOFTWARE CURRENTLY PROVIDES FFT & S-PARAMETER FUNCTIONALITY. NO TIME-FREQUENCY ANALYSIS TOOLS ARE KNOWN TO BE AVAILABLE.

NO MENTION OF THE STFT, WVD OR WT WAS FOUND IN RESEARCHING TDR. IT DOES NOT APPEAR AS THOUGH ~~THE~~ TIME-FREQUENCY ANALYSIS IS CURRENTLY APPLIED TO TDR WAVEFORMS

NO MENTION OF THE STFT, WVD OR WT WAS FOUND IN FAILURE ANALYSIS PUBLICATIONS. IT DOES NOT APPEAR AS THOUGH T-F ANALYSIS IS CURRENTLY APPLIED IN FA.

FREQUENCY ANALYSIS THROUGH THE FFT IS USED OR AVAILABLE FOR TDR & FA.

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PROJECT NAME ~~FDA~~ | DFZ NOTEBOOK NO.

BY USING THE FFT FOR ANALYSIS, THE TEMPORAL INFORMATION IS COMPLETELY LOST. THE TDR SIGNAL IS NON-STATIONARY AND THE TIMES DURING WHICH FREQUENCY COMPONENTS ARE PRESENT ARE CRITICAL FOR ANALYSIS.

BY USING THE WT, FREQUENCY COMPONENTS CAN BE ISOLATED AND ASSOCIATED WITH SPECIFIC CIRCUIT COMPONENTS RATHER THAN JUST THE CIRCUIT AS A WHOLE.

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